

Communications Research for Command & Control: Human-Machine Interface Technologies Supporting Effective Air Battle Management



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The Domain





The Problem



- **Noise**
 - Relatively diffuse jet engine noise coupled with highly directional noise due to machinery
 - Long duration flights can lead to hearing loss
 - Loud external noise environments leads to increased volume of comm channels, which leads to more hearing loss





The Problem



- **Communications**
 - Multiple simultaneous communications from sources on and off the jet
 - Important communications made difficult to hear by both noise environment and other comms
 - Exacerbated by hearing loss





The Solution?



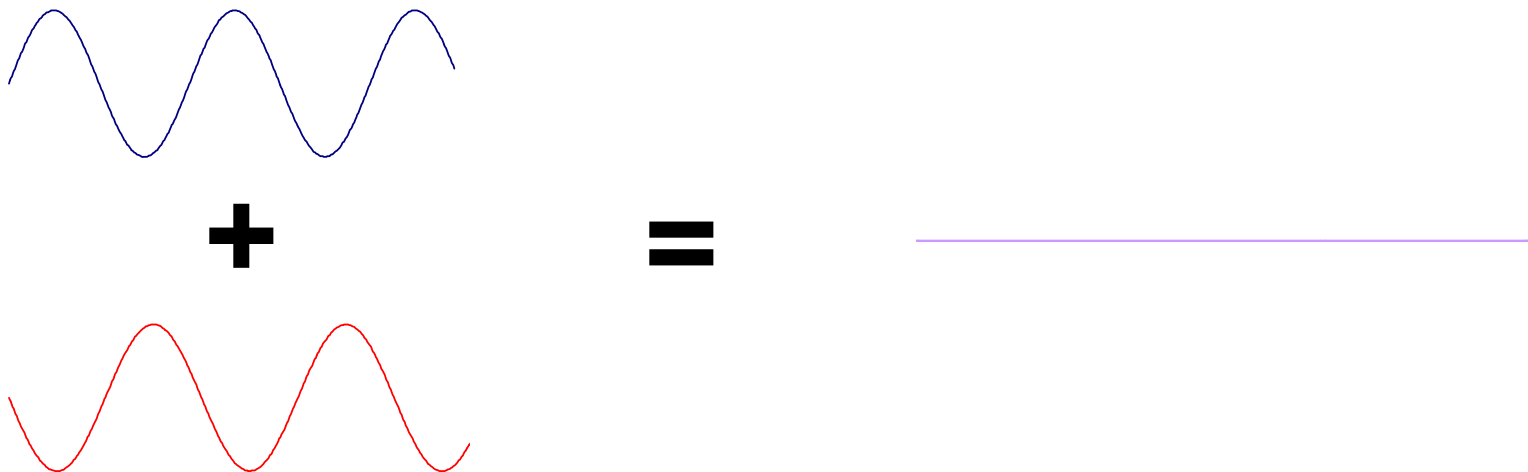
- **Active Noise Reduction (ANR)** has the potential to reduce hearing loss and improve speech intelligibility
- **Spatial Audio** technology has been demonstrated to improve intelligibility in multi-channel communications environments



Active Noise Reduction



- Uses microphone to measure external noise field
- Creates a noise source with the same frequency spectrum but reversed phase
- Adding the phase-reversed sound to the original sound cancels the noise
- Works well only for low frequencies





Active Noise Reduction



- **AFRL researchers measured the AWACS noise environment**
- **Determined that ANR headsets could improve communication effectiveness and reduce hearing loss for AWACS operators**
- **Problems**
 - Long duration
 - Net-4





Active Noise Reduction



- **ANR Headset Evaluation**
 - AFRL asked by ESC/AW to evaluate candidate ANR headsets for acquisition
 - 10 vendors offered headsets for a “fly-off”
 - Combat training sorties flown out of Tinker AFB, OK
 - Crew members randomly assigned to one of the ANR headsets
 - Post-flight questionnaires





Active Noise Reduction



- **ANR Headset Evaluation (continued)**
 - **Objective Measures**
 - Noise Attenuation Performance
 - Headset Clamp Strength
 - Weight
 - Battery Pack Weight
 - Battery Configuration
 - **Subjective Measures**
 - Fit
 - Comfort
 - Usability
 - Audio Quality
 - Subjective Hearing Protection
 - Fatigue



Active Noise Reduction



- **Second evaluation phase**
 - **1st- and 2nd-place headset vendors provided additional headsets which were worn by randomly selected operators during normal duty for four weeks**
 - **Survey assessment tool indicated**
 - **Bose headset considered a substantial improvement relative to current headset**
 - **2nd-place headset more prone to comfort and usability issues**
 - **Use of ANR reduced perceived Net-4 time**
 - **Bose headset selected for acquisition, and is currently in use in the AWACS fleet**



Spatial Audio Displays



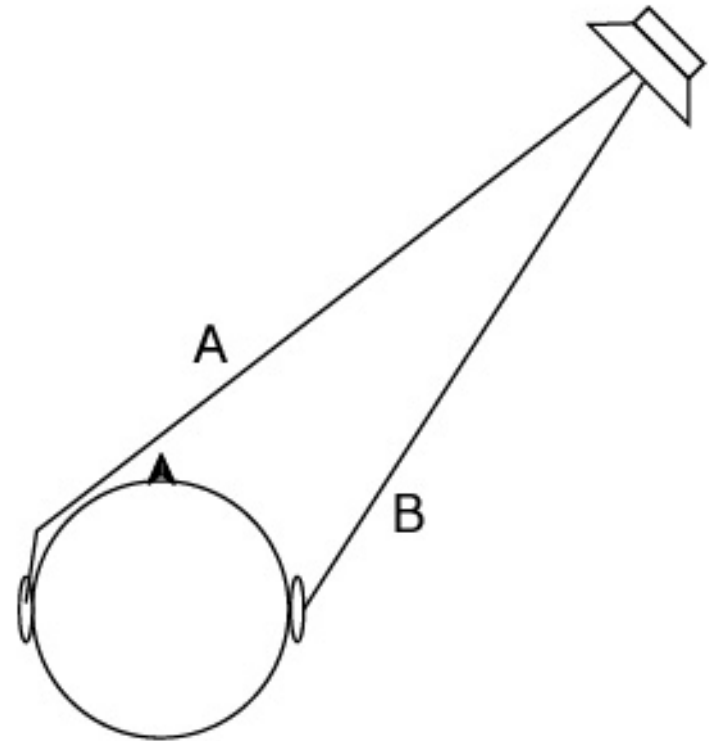
- In natural environments, listeners make use of spatial cues to more efficiently segregate speech channels
 - Enhanced Speech Intelligibility
 - Reduced Workload
 - Improved Situation Awareness
- Spatial Audio Displays are designed to simulate naturally occurring spatial cues and present them to listeners via headphones
- What are the cues that allow humans to localize sound?
 - Interaural Time Differences (ITDs)
 - Interaural Level Differences (ILDs)
 - Head-Related Transfer Functions (HRTFs)



Spatial Audio Displays



- ITDs
 - Sounds arrive at the ear closest to the source about 0-800 μ s before they arrive at the ear furthest away, depending on the angle of incidence
 - The brain can detect these differences and uses them to determine the location of a sound source
 - Works for low-frequency sounds (up to 1500 or 2000 Hz)

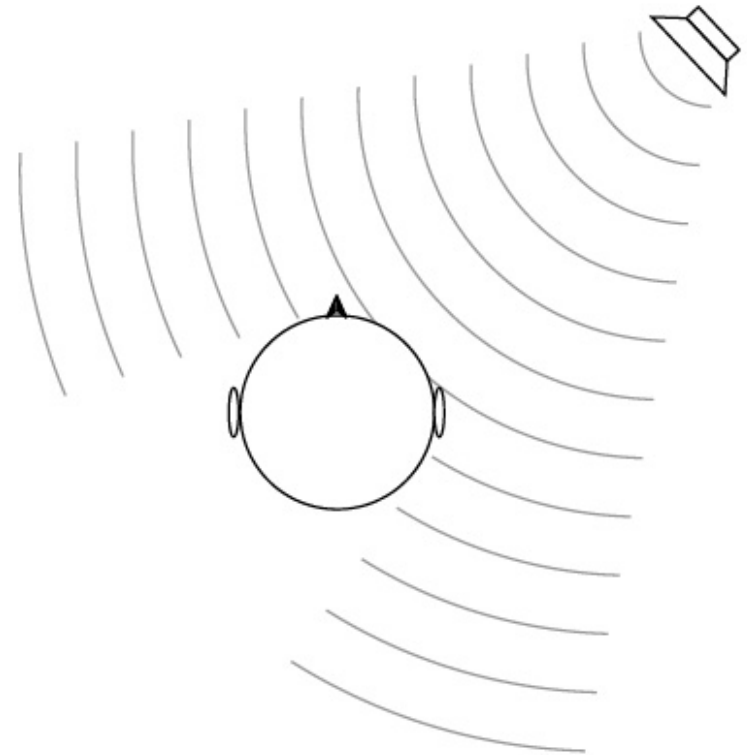




Spatial Audio Displays



- ILDs
 - Sounds are louder at the ear closest to the source than at the ear furthest away, due to head shadow
 - The brain can detect these differences and uses them to determine the location of a sound source
 - Works for high-frequency sources (above 3000 Hz)



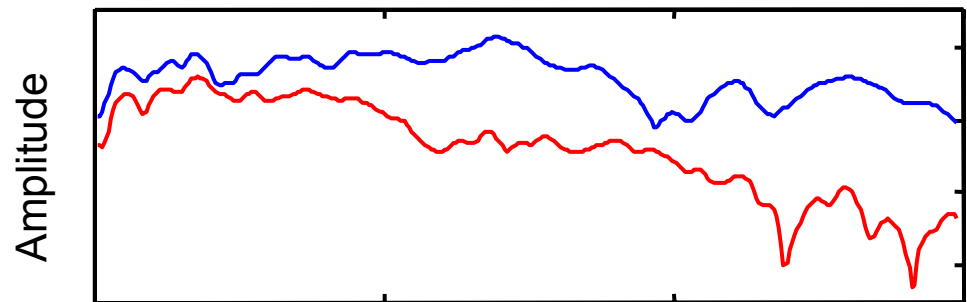
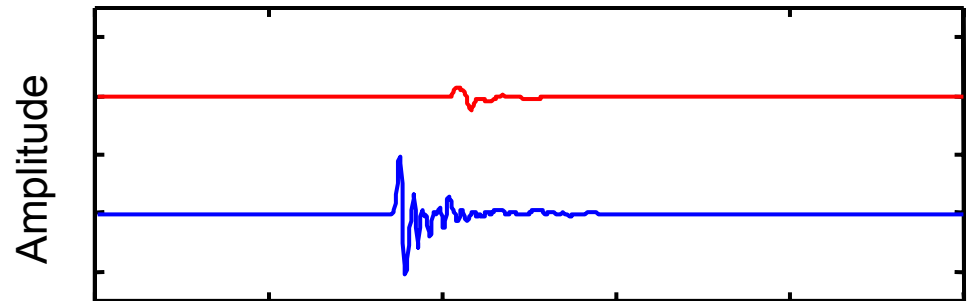


Spatial Audio Displays



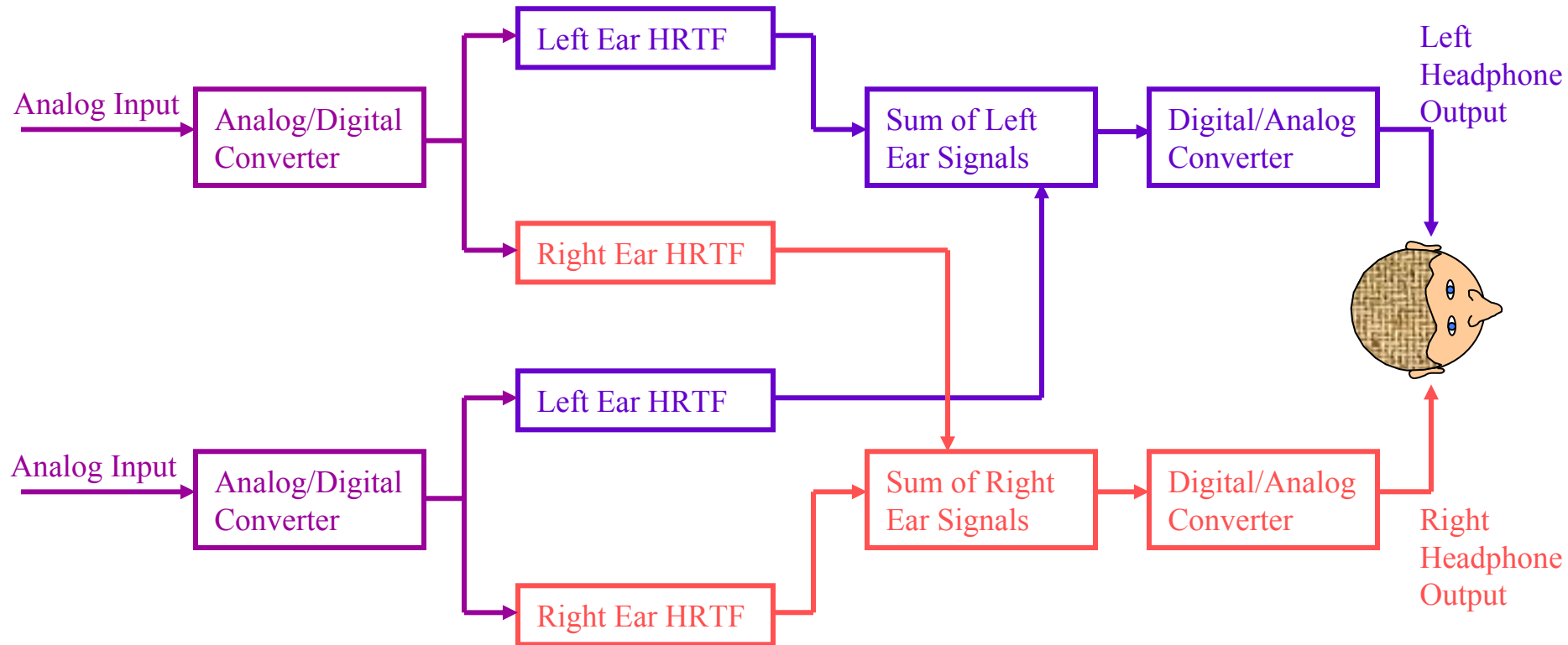
- HRTFs
 - By the time sound reaches the eardrum, it has been modified by interactions with the head, torso, and outer ears
 - The magnitude of these modifications varies as a function of frequency
 - The brain uses these cues to determine the front/back and up/down components of a sound source's location
 - Highly individualized
 - Contains ITD and ILD information

Sound source at $+90^\circ$ Azimuth, 0° Elevation





Spatial Audio Displays



Schematic of a two-channel spatial audio display generator



Task: Coordinate Response Measure (CRM)



- Developed at AFRL in 1980 as a basic task relevant to military communications
- 256 phrases per talker
- “Ready *call sign* go to *color-number* now”
 - 8 call signs (Arrow, Baron, Charlie, Eagle, Hopper, Laker, Ringo, Tiger)
 - 4 colors (Red, Blue, White, Green)
 - 8 numbers (1-8)
- Task: Select the color-number combination spoken by the talker who spoke your assigned call sign (selective attention)



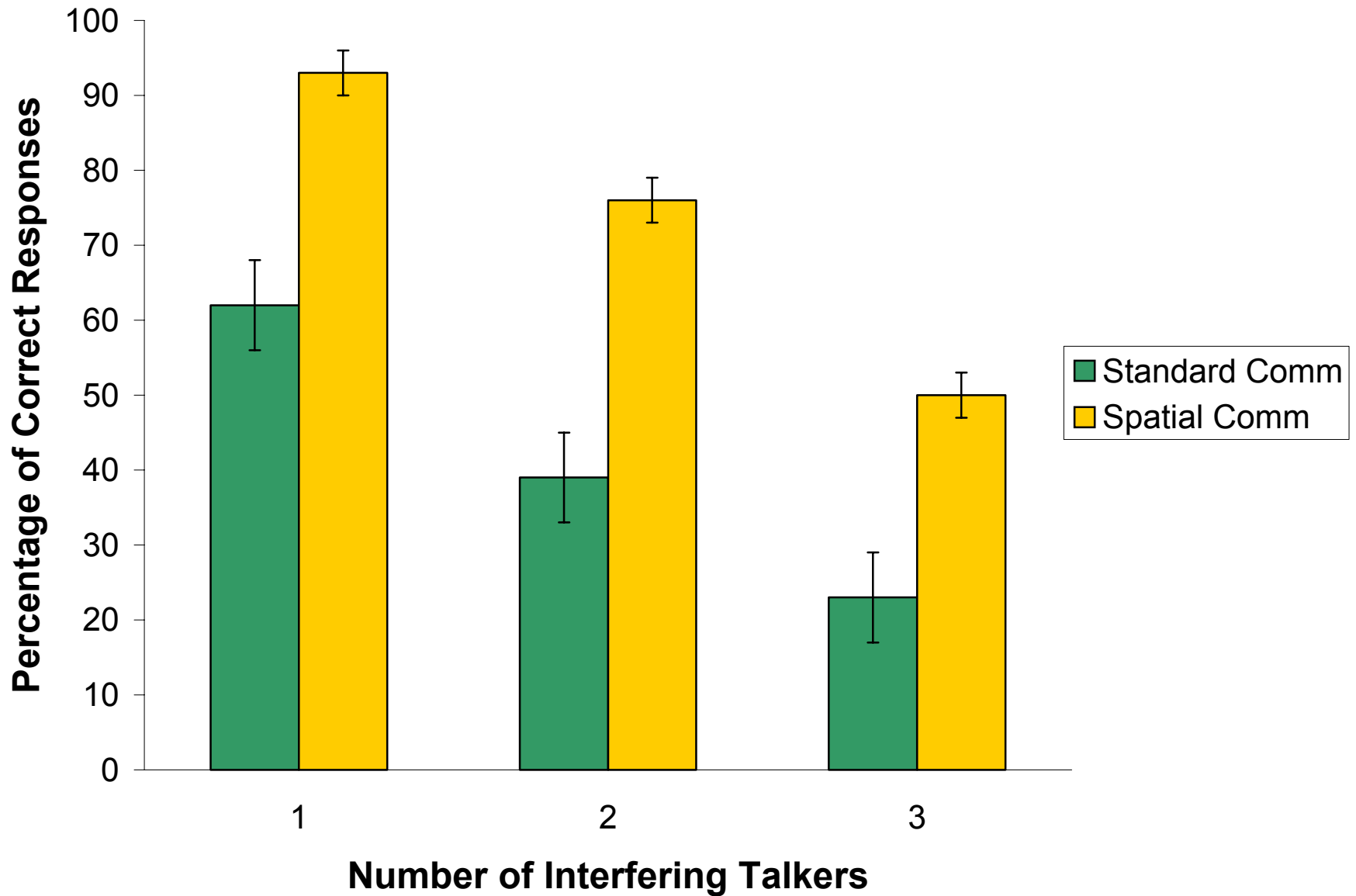
Task: Coordinate Response Measure (CRM)



“Ready Baron go to Blue Five Now”

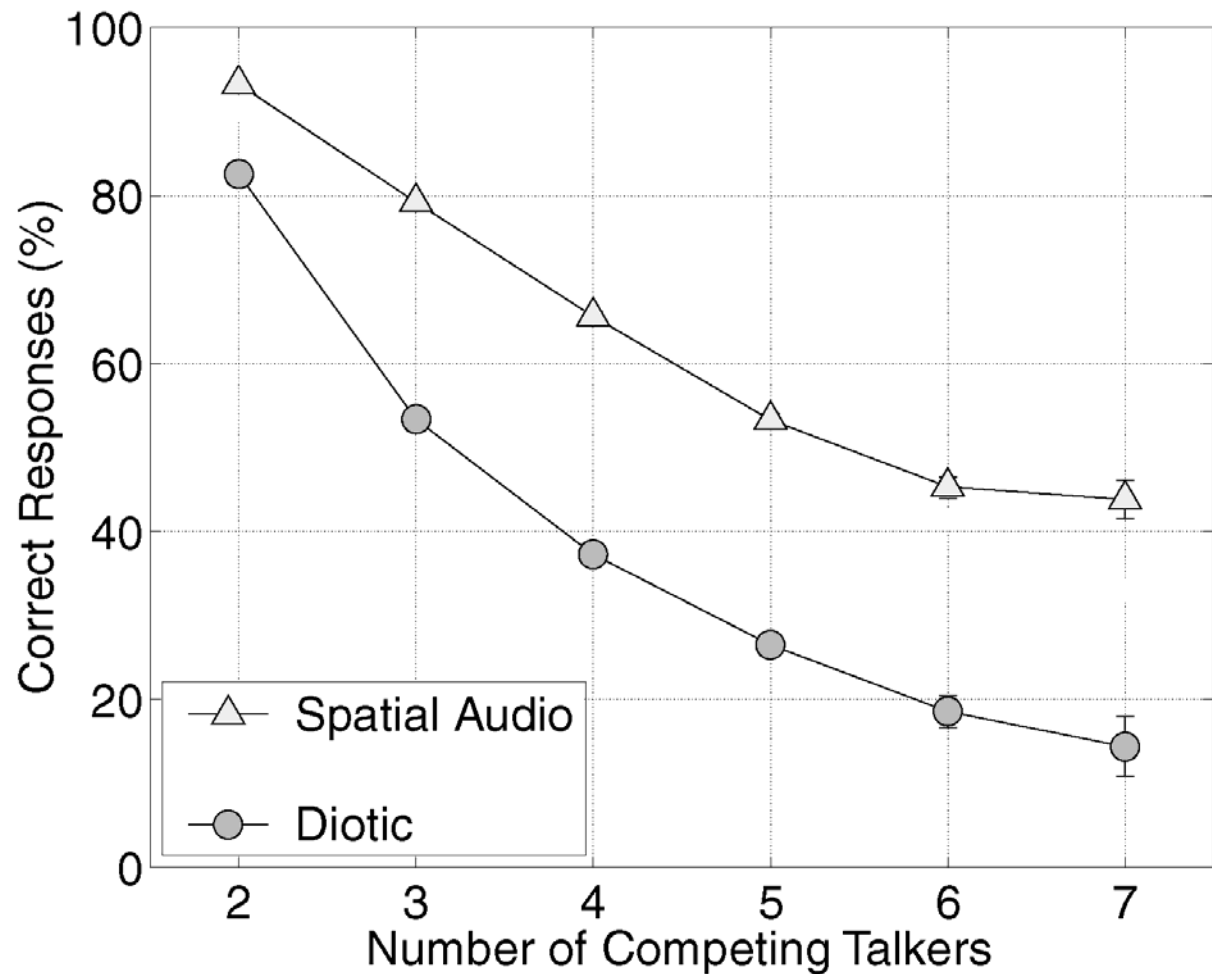
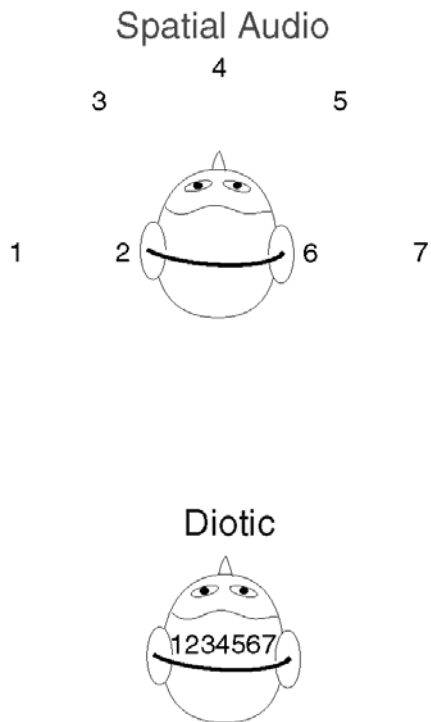


Typical Data



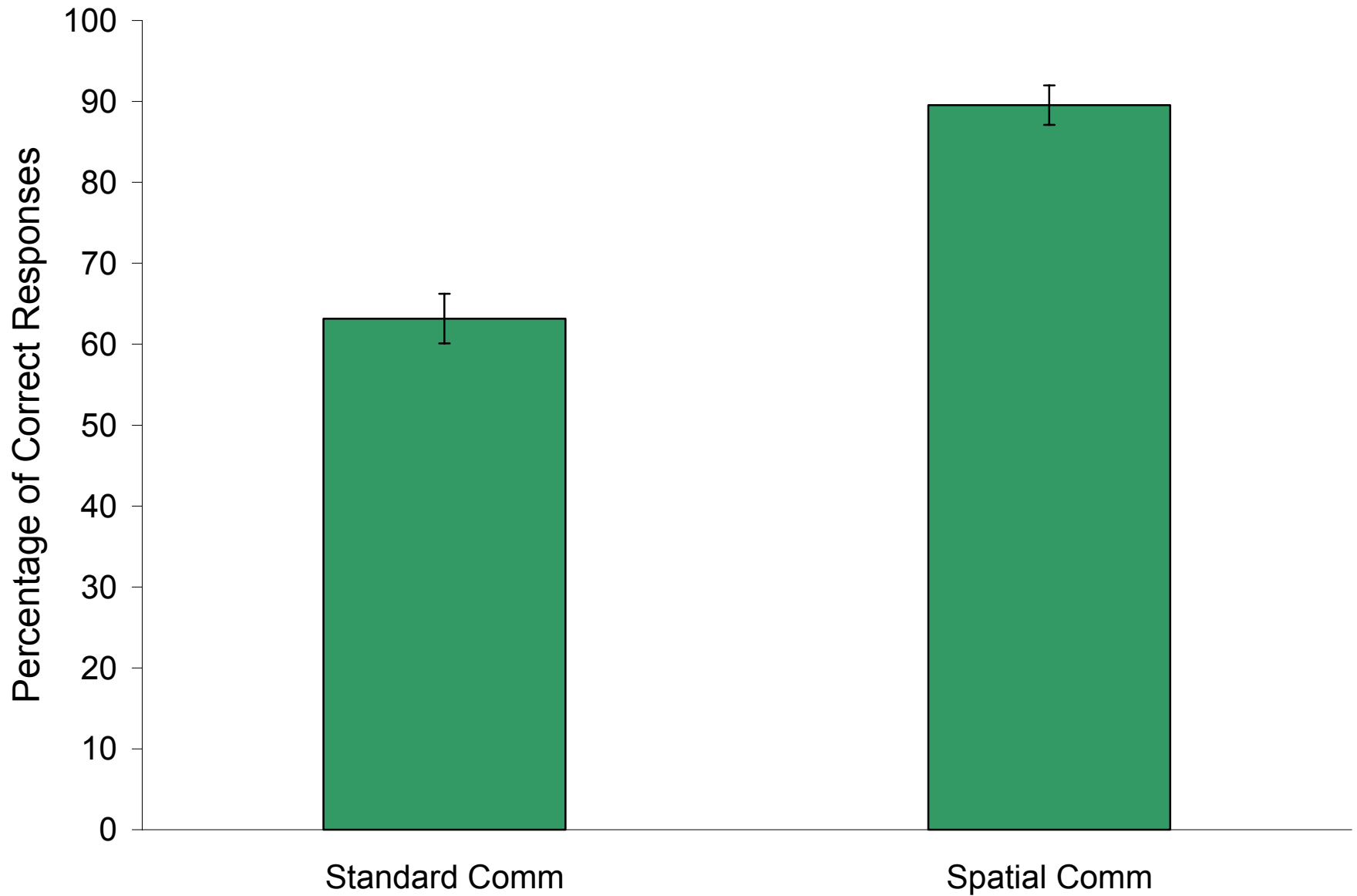


Optimized Configuration



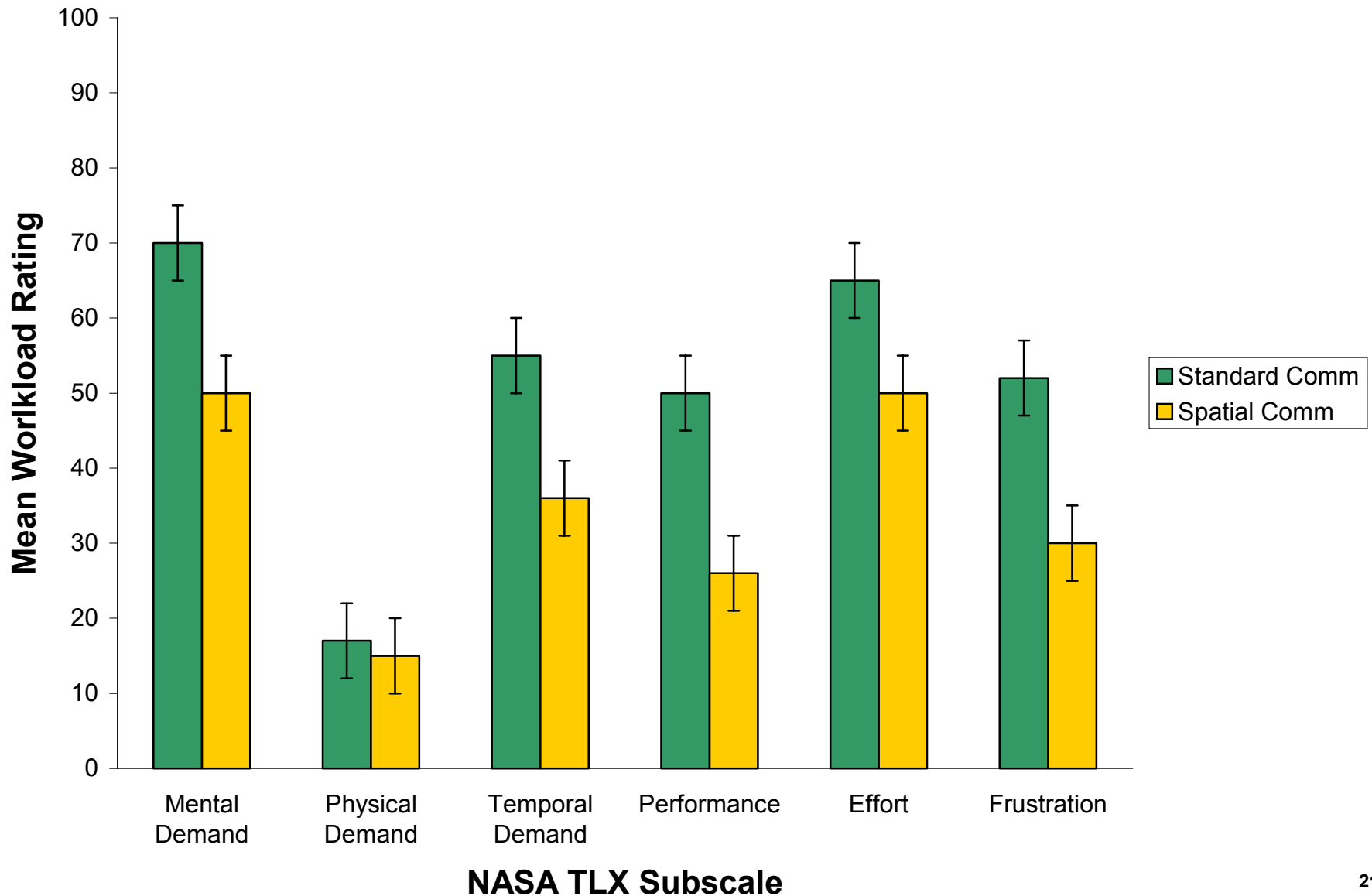


Studies at Tinker AFB





Studies at Tinker AFB

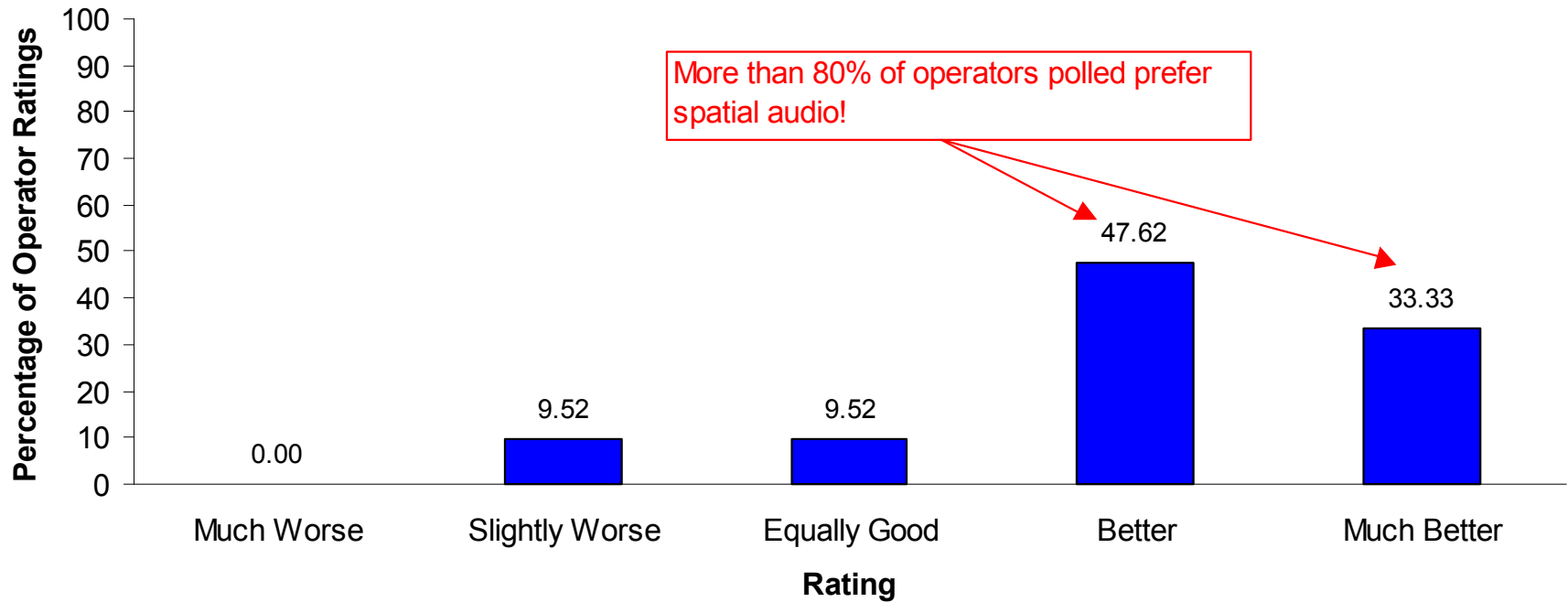




Studies at Tinker AFB



"How would you rate your satisfaction with the spatial audio intercom compared with the intercom you use operationally?"





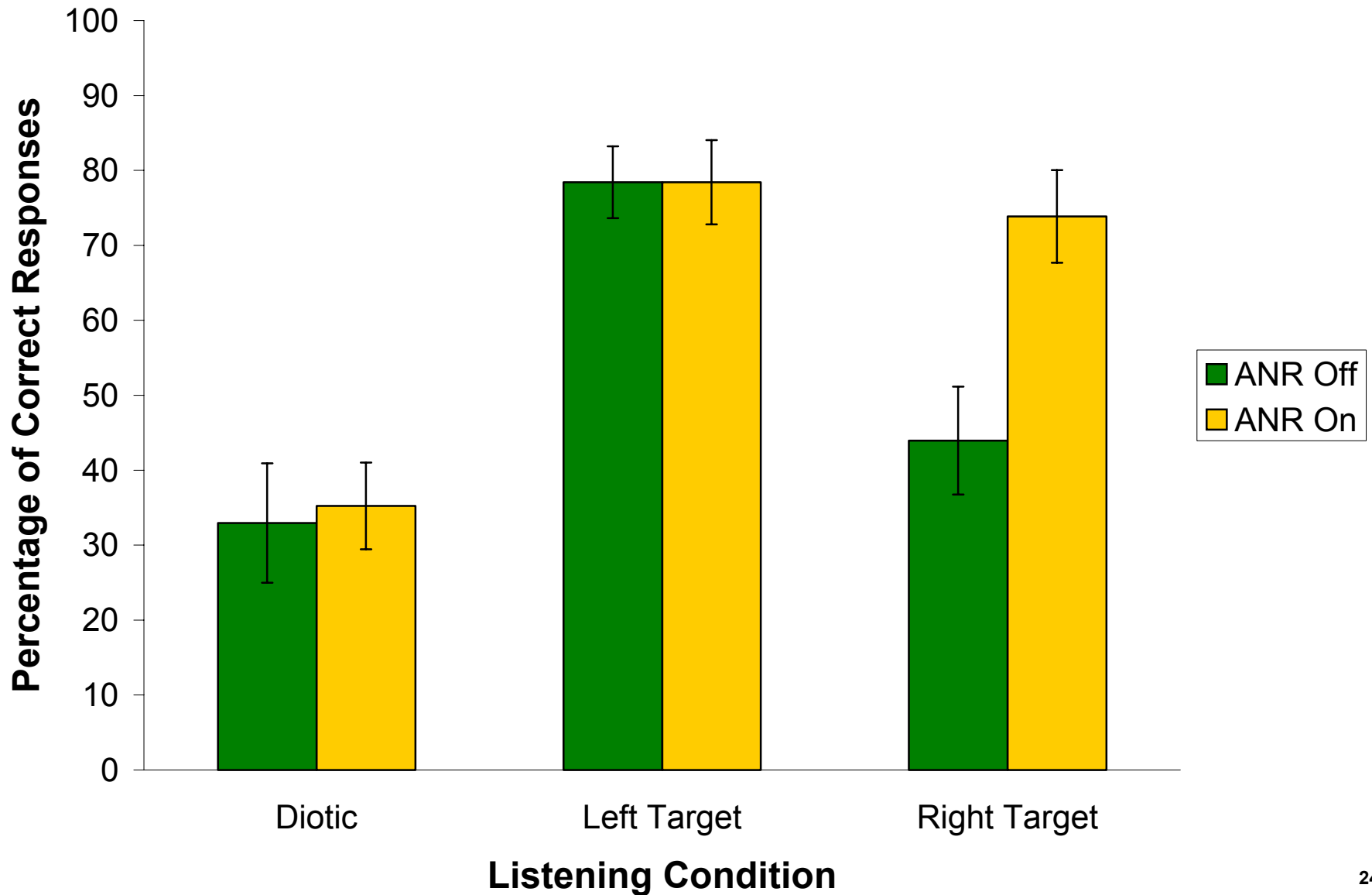
Studies Aboard AWACS



An AWACS operator participating in the experiment



Studies Aboard AWACS





Operational Use



CKI 30n [Ver. 2.0] - © 2002 by Federal Systems Division, Compunetix, Inc.

USER: SYS MSG: MIC: SYS PORT: SCC COMM DAP COMM FCI SYNC

SPATIAL AUDIO					
90 _r	90 _f	30 ₋	30 ₊	10 ₋	10 ₊
Not Assigned	Not Assigned	Not Assigned	Not Assigned	Not Assigned	Not Assigned
Not Assigned	Not Assigned	Not Assigned	Not Assigned	Not Assigned	Not Assigned
Not Assigned	Not Assigned	Not Assigned	Not Assigned	Not Assigned	Not Assigned
Not Assigned	Not Assigned	Not Assigned	Not Assigned	Not Assigned	Not Assigned
Not Assigned	Not Assigned	Not Assigned	Not Assigned	Not Assigned	Not Assigned
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Not Assigned	Not Assigned	Not Assigned	Not Assigned	Not Assigned	Not Assigned
Not Assigned	Not Assigned	Not Assigned	Not Assigned	Not Assigned	Not Assigned
Not Assigned	Not Assigned	Not Assigned	Not Assigned	Not Assigned	Not Assigned

0 dB 0 dB 0 dB DTMF Key Gain

Handset Ring Speaker Ring Speaker Volume

Log Out Clean Screen Reset DAP Exit Foot Switch NONE Local Ovrd NONE Ring TYPE 1

Main Menu System Info Spatial Audio VOX OFF Voice Act OFF Call Fwd --- Handset Ring OFF

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Operational Use



- ***“With the use of the volume controls and the various bucket positions I had total SA on the fight. I could tell the difference between my aircraft and the adversaries and was fully aware when the pilots were talking on the common safety frequency. This is the first time in my 16 year career that I have fully heard and comprehended a multi-frequency mission.”***
- ***“Increases SA as to what radio (frequency) someone is talking on. Cuts down on guessing what radio a TX came across.”***
- ***“I think the system/capability is very useful for certain missions. As an SD listening to 5 or 6 different frequencies, it makes a big difference helping you allocate SA to listen to a particular freq.”***



Operational Use



- **ANR Headsets**
 - Currently used by 552nd ACW (USAF AWACS)
 - Being considered for other BMC2 platforms
- **Spatial Comm**
 - Currently used at USAF Weapons School
 - Requirement for Block 40/45 AWACS upgrade
 - Being considered by JSTARS, E-2C



Questions

